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RELATIONSHIPS BETWEEN DRAINAGE AREA CHARACTERISTICS AND NON-POINT SOURCE NUTRIENTS IN STREAMS

Pacific Northwest Environmental Research Laboratory

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16. ABSTRACT

National Eutrophication Survey data for 143 drainage areas in the north-central and northeastern United States affected only by non-point sources were studied to determine relationships between general land use and stream nutrients. Both total nitrogen and total phosphorus concentrations and loads in streams were considered.

Mean annual nutrient concentrations were significantly higher in streams draining agricultural lands than in those draining forested watersheds and these differences were greater for total phosphorus (0.151 as compared to 0.014 mg/1) than for total nitrogen (3.10 as compared to 0.77 mg/1). Animal density had a significant effect on both nitrogen and phosphorus concentrations in streams.

Little correlation was found between stream nutrient loads and overall land use. Cursory analysis of soils, topography, and climate suggest the development of possible nutrient load prediction models, to be accomplished in the next phase of the study.

The study represents a preliminary report, with subsequent reporting to include analysis of data on approximately 1,000 subdrainage areas covering a nationwide variety of climatic, geographic, and land use conditions.

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RELATIONSHIPS BETWEEN DRAINAGE AREA CHARACTERISTICS AND NON-POINT SOURCE NUTRIENTS IN STREAMS

WORKING PAPER NO. 25

A Preliminary Analysis of National Eutrophication Survey Data From 143 Drainage Areas in Northeastern and Northcentral United States

National Eutrophication Survey
Pacific Northwest Environmental Research Laboratory
Corvallis, Oregon

August, 1974

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I. INTRODUCTION

A. History and objectives

The initial planning for the National Eutrophication Survey (NES) visualized a detailed watershed land use study for each of the approximately 750 lakes which was to be done in parallel with the field sampling program. The idea was to develop a quick and relatively accurate method of assessing nutrient loadings to lakes based on land use analysis of their watersheds.

The original concept of a land use study for every lake underwent several modifications, evolving to its present state--a study of over 1,000 drainage areas, nearly all of which are within the watersheds of lakes being studied by the National Eutrophication Survey.

As it is now envisioned, the basic objective of the NES land use study is to investigate the relationships between general land use types and nutrient runoff in streams with an aim of developing nutrient (nitrogen and phosphorus) runoff coefficients based on land use and related geographical characteristics. The revised title of the study, Relationships Between Drainage Area Characteristics and Non-point Source Nutrients in Streams, reflects this objective. The project is tied in with a massive stream and lake sampling program and will include a large number of drainage

areas covering a nationwide variety of climatic and geographic conditions. This affords a unique opportunity to look at the land use--nutrient loadings--eutrophication picture on a national scale, and develop a system utilizing coefficients, or a range of coefficients, to reflect geographical or regional differences.

The distribution of land use study areas within the first two groups of states covered by the National Eutrophication Survey is illustrated in Figure 1. In the area in which tributary sampling began in the summer of 1972, 143 drainage areas have been selected for land use analysis. Approximately 380 drainage areas have been selected in the NES study area where sampling was initiated in 1973. In the remainder of the contiguous United States, where sampling began in 1974, about 500 drainage areas will be included.

B. Literature

Considerable effort has been expended recently to study the effects of land use on nitrogen and phosphorus runoff. In general, these efforts have intensified in the past four years or so with increased concern for developing methods of quantifying and monitoring nutrient export from areal sources. However, most of the studies have been limited to investigations of one lake or a small geogrophical area. Findings from some of the more frequently cited studies are shown in Table 1. For ease in comparison and interpretation, the data were converted to a common

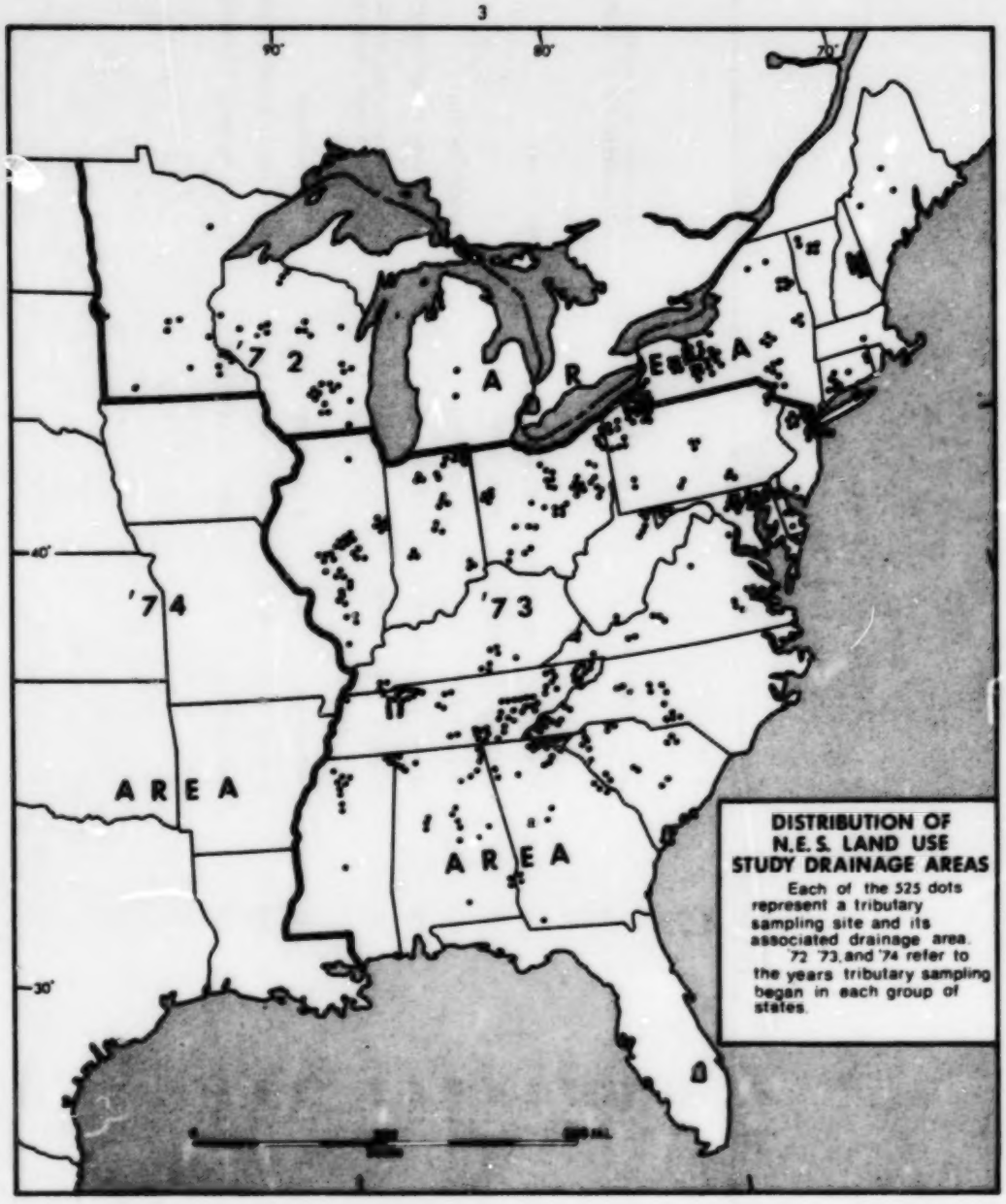
90°
80°
70°
40°
30°
'72
AREA
'74
'73
AREA
AREA
DISTRICTION OF
N.E.S. LAND USE
STUDY DRAINAGE AREAS
Each of the 525 dots represent a tributary sampling site and its associated drainage area. '72 '73, and '74 refer to the years tributary sampling began in each group of states.

Figure 1.

TABLE 1

Data From Literature on Nutrient

Export by Land Use Type

General Land Use	Total N_2 (lbs/mi^2/yr)	Total P_2 (lbs/mi^2/yr)	Reference	Geographical Location	Remarks
Forest	-	205	Sylvester (1961)	Washington	
	1,895	474			
	832	493			
Forest	2,840	63	Cooper (1969)	N. Minnesota	Data given for 4 months, extrapolated for 12 months
	2,542	104			
	752	48			
	1,902	77			
Forest	876	60	Jaworski & Hetling (1970)	N.E. West Virginia	88% forest
Forest	1,400	27	Taylor et al. (1971)	Cent. Ohio	
Agriculture	4,465	255	Sawyer (1947)	S. Wisconsin	General farmland
Agriculture	2,316	730	Witzel et al. (1969)	S.W. Wisconsin	Higher than normal runoff
Agriculture	725	61	Minshall et al. (1969)	S.W. Wisconsin	Base flow averages for 36 natural drainage areas, over 90% agriculture
Agriculture	2,446	155	Jaworski et al. (1969)	W. Cent. Maryland	80% agriculture
Agriculture	2,490	749	Minshall et al. (1970)	Md. and Wash. D.C.	Small research control plots
Agriculture	2,196	122	Anon. (1971)	Cent. N. Carolina	Mostly pasture. Six-month sampling

TABLE 1
(Page 2)

General Land Use	Total N_2 (lbs/mi^2/yr)	Total P_2 (lbs/mi^2/yr)	Reference	Geographical Location	Remarks
Urban	5,696	522	Weibel et al. (1964)	Cincinnati	Stormwater runoff
Urban	1,216	584	Burm et al. (1968)	Ann Arbor	
Urban		709	Bryan (1970)	Durham	
Urban	1,241	-	Jaworski & Hetling (1970)	Wash. D.C. metro. area	60% urban
Urban	-	627	Sonzogni & Lee (1972)	Madison	
Mixed	2,063	141	Frink (1967)	Connecticut	Rural, 50% forested
Mixed	1,107	15	MacKenthun et al. (1968)	Maine	Rural
Mixed	1,220 1,050 1,370 1,720	64 48 41 82	Johnson & Owen (1971)	S.E. Ontario	50% agriculture, 50% forest

export rate, lbs/mi^2/yr. Little consistency can be found in land use - nutrient export relationships from one study to another, with the exception of the somewhat uniformly high total P export rates from urban areas.

Two very recent works have addressed the problem on a larger scale, having attempted to develop systems for estimating nutrient runoff from land use based on coefficients developed entirely, or in part, from literature reviews. Dillon and Kirchner (1974), further defining land use by geological classification, derived total phosphorus ranges and mean values from a study of 31 watersheds in southern Ontario and 12 additional watersheds from literature sources (Table 2).

TABLE 2

Ranges and Mean Values for Export of Total Phosphorus from 43 Watersheds*
(in mg/m^2/yr)

Land Use	Geological Classification	
	Igneous	Sedimentary
Forest		
Range	0.7-8.8 (4-50)	6.7-18.3 (30-104)
Mean	4.7 (26.8)	11.7 (66.8)
Forest & Pasture		
Range	5.9-16.0 (33.7-91.4)	11.1-37.0 (63.4-211.3)
Mean	10.2 (58.2)	23.3 (133.0)

* Data in parentheses in lbs/mi^2/yr.

With considerable qualification, Uttormark et al. (1974) have presented typical values of nutrient runoff coefficients from an extensive literature review (Table 3).

TABLE 3

Typical Values of Nutrient Runoff Coefficients*

Land Use	High	Low	Ave.
	Total N (kg/ha/yr)		
Forest	5.0 (2,856)	1.0 (571)	2.5 (1,428)
Agriculture	10.0 (5,711)	2.0 (1,142)	5.0 (2,856)
Urban	10.0 (5,711)	2.5 (1,428)	5.0 (2,856)
	Total P (kg/ha/yr)		
Forest	0.8 (456)	0.05 (29)	0.2 (114)
Agriculture	1.0 (571)	0.1 (57)	0.3 (171)
Urban	5.0 (2,856)	1.0 (571)	1.5 (857)

* Data in parentheses in $lbs/mi^2/yr$.

They suggested these values might be useful in estimating nutrient loadings to lakes, but warned that they were obtained without regard to geographical location-the high, low, and average figures not being representative of all parts of the country.

It would seem that uniformity in procedure, which is largely lacking from one study to another, would limit the validity of comparing the results of one with another, or using combined results to establish nutrient loading coefficients. More important, there is an insufficient quantity and an inadequate

distribution of data points available in literature sources to enable a study of the regional aspects of nutrient runoff.

II. DATA COLLECTION METHODS

A. Selection Criteria

Factors involved in the selection of drainage areas were:

1. Availability of accurate topographic maps for drainage area delineation.

2. Availability of usable aerial imagery (preferably in scales between 1:40,000 and 1:80,000) and/or existing land use studies for identifying land use.

3. Sufficient watershed relief to render surface runoff a significant factor.

4. Absence of indirect drainage areas (sub-watersheds associated with nutrient traps such as impoundments) upgradient from the sampling site.

5. Absence of identifiable point sources. A few of the '72 drainage areas (12 of the 143) contain known point sources; however, nutrient concentration and export data for these have been adjusted to reflect only non-point source impact.

6. Need to encompass a variety of geographic and climatic areas and obtain, where possible, land use homogeneity within subdrainage areas.

There are a few exceptions to these criteria to accomodate study of particular types of areas. Within the '73 study area, 15 heavily mined watersheds and 15 predominantly urban (but without apparent industrial or municipal wastewater treatment facilities have been included.

In considering drainage areas for land use analysis from the '72 NES lake watersheds, it was necessary to choose from subdrainage areas for which tributary sampling sites were selected solely

for purposes of determining nutrient loadings to lakes. Major emphasis at the onset of the survey was on point source impact on lakes, particularly municipal wastewater treatment plant discharges. At the time tributary sites were being selected for '73 study area lakes, emphasis was still on point sources. However, there was an opportunity to choose additional sites where their inclusion was warranted by land use homogeneity and other factors rendering suitability for land use vs. nutrient runoff analysis. Very recently, more emphasis has been focused on non-point source impact on lakes and this has influenced tributary sampling site selection for lakes in the '74 study area. In a few instances, where it was determined necessary to achieve a better geographic distribution of drainage areas, sites have been selected outside NES lake watersheds.

B. Drainage Area Measurement and Land Use Identification

Following tributary site selection, individual drainage areas are delineated on U.S. Geological Survey (USGS) topographic maps and their areas determined by use of a compensating polar planimeter. General land use identifications are made using late-data aerial photography and/or recent land use maps. Land use categories covered are: (1) forest, (2) cleared-unproductive, (3) agriculture, (4) urban, (5) wetland, and (6) other (including barren, extractive and open water). These types roughly correspond in level of

classification to Level I of the recently developed USGS Land Use Classification System*.

C. Land Use Percentage Computation

For each drainage area, percent coverage of each land use type is compiled by use of equadistant dot pattern overlays. The dot patterns are placed in a random fashion over the USGS map overlays on which land use units have been drawn. To determine the land use percentage for a given drainage area, the number of dots that fall on each land use category is totaled; each of the totals is multiplied by 100, and the resulting products are in turn divided by the total number of dots falling in the drainage area. Dot pattern densities may vary from one drainage area to another depending on the overall size of the drainage area; generally, the larger the area the less dense the dot pattern.

D. Animal Unit Density Computations

It is generally known that animal wastes are major contributors to the nitrogen and phosphorus in agricultural land runoff. Early in the course of this study, it seemed some mechanism should be developed to enable analysis of this aspect of agricultural runoff. Because of shifts in agricultural land usage, particularly

* A Land-Use Classification System for Use With Remote-Sensor Data. U.S. Department of Interior, Geological Survey Circular 671, 16 pp. (1972).

from season to season and year to year, it seemed impractical or impossible to accurately separate pasture from cropland. Rather, it appeared a more expeditious method would be to determine overall animal densities (i.e., animal units per acre of subdrainage area).

The quantities of total nitrogen and total phosphorus produced annually by beef cattle and hogs have been computed from data presented by Miner and Willrich (1969). For ease in data handling, no distinction has been made between dairy and beef cattle. Phosphorus and nitrogen production data for sheep are from Vollenweider (1968). These data are presented in Table 4.

TABLE 4

Animal Nutrient Production (lbs/yr/head)

	Total N	Total P
Cattle	127.7	15.9
Hogs	21.9	3.2
Sheep	20.7	3.3

To convert to animal units equaling one beef animal for nitrogen, hogs must be multiplied by a factor of 0.17, and sheep must be multiplied by 0.16. To convert to animal units for phosphorus, factors of 0.20 and 0.21 are used for hogs and sheep, respectively.

Animal unit densities for each nutrient for individual drainage areas are obtained by first determining animal units per acre of agricultural land in counties occupied by study drainage areas. For drainage areas located in more than one county, weighted unit densities are determined based on the amount of each drainage area's agricultural land in each county. Then, these figures are simply multiplied by the respective drainage area's percent in agriculture to achieve densities (animal units/acre) related to entire drainage areas. Data for these computations are obtained from U.S. Census of Agriculture publications or, where available, more recent state agricultural statistical reports (Anonymous, 1972; Anonymous, 1973).

E. Other Procedures

Explanations of the following procedures are given in NES Working Paper No. 1:

1. Tributary sampling methods and handling.
2. Analytical methods (stream samples).
3. Nutrient loading estimates.
4. Stream flow estimates.

It should be noted that nutrient exports are computed using "mean estimated" loadings (which are adjusted for seasonality and the year of sampling), and to drainage area measurements as determined by NES. Mean estimated loadings were unavailable for a

few sites where the USGS had not provided flow estimates. In these cases, flow estimates were calculated by NES based on runoff patterns in adjacent, overlapping, or nearby areas for which USGS estimates were provided. Loadings for these drainage areas are estimated according to the following equation:

$$\text{Annual Load} = (C)(F)(5.3935)(365)$$

where:

C = Mean annual concentrations in milligrams per liter

F = Mean normalized annual stream flow in cubic feet per second

In several cases regarding '72 drainage areas, inconsistencies exist between NES planimetered area figures and those given by USGS; most are apparently in drainage area definition or misinterpretation of tributary sampling site locations. Where time hasn't allowed rectification of these differences, adjustments in flow or area data have been made by NES. All inconsistencies will be resolved with USGS prior to the final report.

III. DISCUSSION OF RESULTS

This paper will address analysis of the land use and stream nutrient runoff data compiled for drainage areas within the first group of states covered by the NES and presented in Table 5. The 143 data points included are in northeastern and northcentral United States. Their geographical distribution is illustrated in Figure 1. Subsequent reports will present data on over 380 drainage areas in the remaining states east of the Mississippi and approximately 500 drainage areas west of the Mississippi.

After compiling the data presented in Table 5, several types of data were broken in classes and plotted on maps of the nine-state area utilizing a graduated color shade scheme in an attempt to reveal possible regional patterns. Maps were compiled for total phosphorus concentrations, total nitrogen concentrations, total P exports, and percent agriculture over percent forest ratios. In general, the maps illustrated relatively low concentrations, export values, and agriculture/forest ratios in the New England states, and relatively high concentrations, exports, and land use ratios in the northcentral states, with the exception of northern Michigan. Interestingly, the few drainage areas in northern Michigan have soil types similar to those found in much of New England. Efforts will be made to include maps, such as those described above, in future reporting.

TABLE 5

Land Use and Nutrient Runoff Data on 143 Subdrainage Areas in Northcentral and Northeastern United States

STATE / WATERSHED Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export ($lbs/mi^2/yr$) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
MAINE																
Moosehead 2309K1	7.24	97.3	0	0	0	0	2.7	Forest	Spod.	.008	0.657	28.7	1148.8	0	0	1.866
Rangeley 2310B1	15.09	99.3	0	0	0	0	0.7	Forest	Spod.	.010	0.590	32.1	1895.0	0	0	1.595
Sebasticook 2312F1	20.47	54.6	7.2	32.9	0	3.6	1.7	M. For.	Spod.	.017	0.966	61.4	3252.8	.0920	.0914	1.789
NEW HAMPSHIRE																
Winnipesaukee 3303C1	3.04	75.0	4.1	6.7	9.5	2.8	1.9	M. For.	Spod.	.042	0.622	146.2	2165.0	.0178	.0176	1.768
3303D1	0.28	74.2	3.2	16.1	6.5	0	0	M. For.	Spod.	.025	0.348	70.9	1473.7	.0427	.0425	1.765
3303E1	2.37	77.1	4.9	7.8	0.8	7.4	2.0	M. For.	Spod.	.030	0.622	105.1	2183.7	.0207	.0206	1.765
3303F1	1.18	80.0	5.0	15.0	0	0	0	M. For.	Spod.	.018	0.358	67.6	1337.2	.0398	.0396	1.762
3303J1	2.71	82.8	4.4	12.4	0.4	0	0	M. For.	Spod.	.015	0.807	49.4	2577.4	.0360	.0356	1.762
3303K1	7.09	93.5	1.0	4.8	0	0	0.7	Forest	Spod.	.015	0.589	51.6	2044.4	.0139	.0138	1.764
3303L1	15.64	91.5	1.6	2.5	1.6	2.1	0.7	Forest	Spod.	.018	0.676	67.0	2463.5	.0072	.0072	1.764
3303N1	3.34	79.4	7.2	8.3	1.8	3.3	0	M. For.	Spod.	.018	0.504	63.2	1807.4	.0241	.0238	1.761
3303U1	8.88	95.0	0.2	0.9	0.1	2.5	1.3	Forest	Spod.	.017	0.544	59.0	1889.2	.0024	.0024	1.764
3303V1	3.46	94.9	1.1	2.3	0	0	1.7	Forest	Spod.	.020	0.855	69.5	2969.3	.0061	.0061	1.767
3303X1	2.92	96.3	0.7	3.0	0	0	0	Forest	Spod.	.017	0.343	62.1	1287.5	.0079	.0079	1.761
3303Y1	3.80	91.3	2.9	5.8	0	0	0	Forest	Spod.	.020	0.304	70.0	1059.4	.0154	.0153	1.763
330341	6.60	87.3	2.3	7.5	0.1	2.5	0.3	M. For.	Spod.	.017	0.517	58.8	1743.7	.0218	.0215	1.766

TABLE 5
(Page 2)

STATE / WATERSHED / Sub Storet #	Area (mi^2)	Land Use Percentages: For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l): Tot P	Tot N	Export ($lbs/mi^2/yr$): Tot P	Tot N	Animal Density (an. units/acre): Tot P	Tot N	Flow (CFSM)***
VERMONT																
Arrowhead																
501021	8.52	37.1	3.0	59.1	0.8	0	0	M. Agric.	Spod.	.031	1.029	105.3	3495.1	.2488	.2488	1.733
501031	91.20	53.3	9.6	32.8	3.0	1.3	0	M. For.	Spod.	.036	1.034	123.0	3531.7	.1401	.1397	1.735
Waterbury																
501131	2.09	79.5	3.0	17.5	0	0	0	M. For.	Spod.	.021	0.690	82.9	2723.2	.0702	.0702	2.014
501141	8.90	84.6	0.7	13.0	1.7	0	0	M. For.	Spod.	.013	0.742	51.5	2941.1	.0521	.0521	2.014
501151	25.71	81.3	3.5	13.5	0.7	1.0	0	M. For.	Spod.	.020	0.835	79.3	3310.6	.0641	.0641	2.014
501152	54.25	83.8	3.8	10.3	1.6	0.5	0	M. For.	Spod.	.019	0.992	73.2	3811.4	.0414	.0414	2.013
MASSACHUSETTS																
Rochdale																
2509E1	0.70	68.3	13.3	6.0	12.1	0	0.3	M. For.	Spod.	.098	1.632	280.0	4680.1	.0281	.0275	1.417
CONNECTICUT																
Aspinook																
0901C1	0.90	87.4	3.1	7.7	1.3	0.3	0.2	M. For.	Spod.	.041	1.256	153.9	4275.1	.0396	.0394	0.915
0901F1	8.78	82.5	3.8	8.8	0.7	3.7	0.5	M. For.	Spod.	.021	0.959	71.1	3246.9	.0451	.0453	1.720
Hanover																
090581	4.96	46.5	11.3	0.3	39.4	1.6	0.9	Urban	Spod.	.045	1.664	166.8	6196.2	.0011	.0011	1.814
Zoar																
091081	0.66	72.5	13.2	14.3	0	0	0	M. For.	Spod.	.021	0.532	78.7	2033.1	.0476	.0473	1.939
0910C1	9.58	74.3	9.7	6.2	8.2	0.9	0.7	M. For.	Spod.	.032	0.956	130.3	3840.2	.0206	.0205	1.802
0910D1	1.86	40.8	17.5	39.1	1.1	1.5	0	Mixed	Spod.	.031	0.978	114.9	3574.7	.1302	.1294	1.890
0910F1	1.15	69.2	7.2	13.6	9.6	0	0.4	M. For.	Spod.	.018	1.126	64.4	4090.1	.0513	.0510	1.918
0910G1	4.64	68.7	7.3	22.5	0.4	0.2	0.9	M. For.	Spod.	.044	1.416	173.2	5530.9	.0848	.0844	1.846
0910H1	4.74	40.2	17.7	11.9	28.1	1.8	0.3	Mixed	Spod.	.034	1.069	114.1	3587.4	.0396	.0394	1.705

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WATERSHED

Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export (lbs/mi^2/yr) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
NEW YORK																
Canadaigua																
3604A1	29.51	30.7	8.5	57.0	2.0	1.7	0.1	M. Agric.	Alf.	.070	1.841	79.7	2113.1	.0878	.0855	0.585
3604A3	5.62	22.0	3.3	73.4	0	1.3	0	M. Agric.	Alf.	.050	3.057	57.5	3517.7	.1299	.1277	0.585
3604B1	4.34	61.6	15.2	23.2	0	0	0	M. For.	Alf.	.015	0.818	18.1	969.1	.0411	.0404	0.589
3604C1	4.66	56.4	13.7	29.9	0	0	0	M. For.	Alf.	.064	1.392	73.5	1585.2	.0460	.0449	0.576
3604D1	1.29	40.0	28.5	31.5	0	0	0	Mixed	Alf.	.014	0.890	15.2	937.6	.0558	.0548	0.539
3604E1	6.27	50.0	19.8	29.0	1.2	0	0	M. For.	Alf.	.009	0.896	10.0	1003.1	.0613	.0605	0.589
3604H1	44.20	68.9	9.6	18.2	1.2	1.8	0.3	M. For.	Incp.	.030	0.941	65.7	2067.9	.0322	.0317	1.031
Cannonsville																
3605B1	4.36	88.6	5.3	6.1	0	0	0	Forest	Incp.	.016	0.493	47.4	1451.6	.0245	.0245	1.478
3605D1	12.36	77.6	3.1	16.8	0.5	0	0	M. For.	Incp.	.018	0.899	51.7	2646.5	.0753	.0753	1.480
3605E1	19.89	66.2	15.5	17.8	0.3	0.2	0	M. For.	Incp.	.018	0.913	68.4	3404.5	.0714	.0714	1.660
3605F1	1.23	100.0	0	0	0	0	0	Forest	Incp.	.014	0.803	53.9	2982.8	0	0	1.752
Carry Falls																
3606B1	1.90	41.3	0	0	0	56.6	2.1	Forest	Spod.	.018	1.171	62.2	3967.4	0	0	1.734
Cassadaga																
3607B1	0.29	62.8	3.9	33.3	0	0	0	M. For.	Alf.	.029	0.856	108.2	3204.7	.1139	.1137	1.618
3607C1	0.49	76.4	18.6	5.0	0	0	0	Forest	Alf.	.010	0.799	33.1	2600.6	.0171	.0171	1.620
Cayuga																
3608G2	2.63	20.6	27.8	51.6	0	0	0	M. Agric.	Alf.	.021	1.433	44.2	3013.0	.1408	.1397	1.068
3608H1	8.50	27.9	23.1	45.8	0.5	2.7	0	Mixed	Alf.	.022	1.039	46.3	2183.9	.0623	.0609	1.068
3608M1	2.38	21.1	6.3	72.1	0	0.5	0	M. Agric.	Alf.	.027	2.575	22.5	2171.3	.2076	.2062	0.445
3608P2	2.43	11.9	7.0	80.6	0.5	0	0	Agric.	Alf.	.051	1.735	109.3	3717.8	.1813	.1805	1.089
3608Q1	14.40	22.9	4.0	71.0	0.3	1.8	0	M. Agric.	Alf.	.031	1.937	68.6	4223.2	.1597	.1590	1.060
Chautauqua																
3610B1	10.80	47.7	6.4	38.2	1.2	6.4	0.1	Mixed	Alf.	.032	1.007	106.7	3320.6	.1306	.1306	1.684
3610C1	23.42	66.8	14.7	14.6	0.2	3.4	0.3	M. For.	Incp.	.034	0.851	114.8	2879.3	.0499	.0498	1.716
3610D1	9.63	45.9	4.4	45.8	0.2	3.5	0.2	Mixed	Incp.	.017	0.811	26.5	1272.5	.1564	.1562	0.833
3610E1	29.24	56.8	6.6	31.6	2.7	2.1	0.2	M. For.	Incp.	.031	0.807	110.0	2915.9	.0486	.0484	1.689
3610F1	1.59	35.9	10.0	6.3	47.8	0	0	Urban	Incp.	.094	1.340	137.5	1956.3	.0215	.0215	0.770
3610H1	5.96	53.5	11.6	34.4	0.5	0	0	M. For.	Incp.	.031	0.877	112.5	3200.1	.1176	.1173	1.737
3610J1	12.25	62.9	13.5	19.9	0.8	2.7	0.2	M. For.	Incp.	.017	0.706	36.1	2391.0	.0681	.0679	1.718
3610K1	13.41	57.4	5.0	35.8	0.3	1.5	0	M. For.	Incp.	.016	1.176	46.2	3518.2	.1224	.1221	1.652

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WATERSHED Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wat.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export ($lbs/mi^2/yr$) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
NEW YORK																
Goodyear																
3613B1	11.39	51.9	1.6	40.4	1.1	5.0	0	M. For.	Incp.	.025	1.191	72.5	3433.0	.1462	.1458	1.469
3613C1	2.19	41.3	1.5	56.4	0	0.8	0	M. Agric.	Incp.	.026	0.982	92.1	3560.7	.2042	.2036	1.489
3613D1	3.95	74.4	5.9	17.6	0	2.1	0	M. For.	Incp.	.018	0.960	53.6	2802.3	.0637	.0636	1.480
3613E1	12.58	58.3	5.0	32.4	1.1	3.1	0.1	M. For.	Incp.	.035	1.071	100.7	3080.6	.1173	.1170	1.461
Huntington																
3615A1	0.17	77.4	6.4	0	12.9	3.3	0	M. For.	Incp.	.038	0.987	112.4	3086.1	0	0	1.421
Cauka																
3617B1	1.30	39.9	13.6	38.1	8.4	0	0	Mixed	Incp.	.045	1.108	74.8	1851.4	.0853	.0846	0.748
3617C1	2.30	28.7	8.3	62.4	0	0.6	0	M. Agric.	Incp.	.017	1.551	26.3	2406.6	.1342	.1342	0.737
3617D1	34.64	41.2	20.4	35.3	0.2	2.1	0.8	Mixed	Alf.	.033	1.058	49.8	1607.5	.0644	.0630	0.735
3617F1	3.17	27.3	22.6	48.4	0.8	0.9	0	Mixed	Incp.	.030	1.939	39.8	2838.1	.0745	.0726	0.741
3617H1	1.59	26.0	26.1	47.8	0	0.1	0	Mixed	Incp.	.034	2.044	54.7	3319.7	.1071	.1061	0.761
Otter																
3625B1	0.41	18.9	13.5	62.2	0	5.4	0	M. Agric.	Alf.	.023	2.302	50.9	5172.7	.1399	.1393	1.314
Round																
3630A1	2.91	87.8	3.8	1.8	5.9	0.7	0	M. For.	Incp.	.043	0.963	121.7	2756.2	.0048	.0048	1.441
3630B1	0.88	44.5	3.7	51.8	0	0	0	M. Agric.	Incp.	.074	1.111	273.8	3131.9	.1378	.1373	1.448
3630C1	17.22	34.5	25.3	26.9	5.8	5.0	2.5	Mixed	Incp.	.050	0.912	148.9	2689.6	.0716	.0713	1.443
Schroon																
3634D1	9.68	89.1	1.6	0	4.6	2.4	2.4	M. For.	Spod.	.019	0.890	51.3	2360.2	0	0	1.489
3634D2	8.33	93.7	0	0	0.7	2.8	2.8	Forest	Spod.	.015	1.110	44.0	3253.7	0	0	1.489
3634E1	2.20	94.0	2.4	0	0.8	0	2.8	Forest	Spod.	.012	0.864	39.5	2862.8	0	0	1.488
3634F1	2.31	92.3	0	0	2.8	3.7	1.2	Forest	Spod.	.010	0.901	32.5	2625.1	0	0	1.498
3634G1	23.85	88.8	1.1	0	0.2	6.6	3.3	Forest	Spod.	.013	1.293	39.4	3942.1	0	0	1.489

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Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export ($lbs/mi^2/yr$) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
NEW YORK																
Seneca																
3635D1	14.62	43.0	22.1	32.9	0.6	0.9	0.5	Mixed	Incp.	.019	1.106	59.5	3137.3	.0757	.0740	1.354
3635F2	24.94	42.5	34.2	21.6	0.1	1.5	0.1	Mixed	Alf.	.034	0.936	63.8	2474.4	.0333	.0324	1.349
3635G1	5.22	56.7	24.5	19.0	0.4	0	0.4	M. For.	Alf.	.010	1.576	7.4	1196.2	.0437	.0427	0.381
3635H1	5.51	40.6	32.6	22.5	2.5	1.2	0.6	Mixed	Alf.	.017	1.575	48.1	4504.4	.0346	.0337	1.433
3635L1	9.46	20.3	50.8	24.7	4.2	0	0	Mixed	Alf.	.025	1.007	22.2	898.6	.0336	.0329	1.450
3635M1	12.76	58.8	13.0	22.0	1.7	4.0	0.5	M. For.	Alf.	.021	0.837	55.6	2240.5	.0506	.0495	1.350
Swan																
3636A1	6.57	60.5	8.7	21.6	4.9	4.0	0.3	M. For.	Incp.	.041	1.183	156.9	4565.4	.0765	.0762	1.957
Swinging Bridge																
3637H1	10.56	51.0	25.1	7.4	15.6	0.5	0.4	M. For.	Incp.	.033	1.044	91.2	2886.3	.0262	.0261	1.405
Conesus																
3639A1	1.87	25.0	3.6	65.4	0	0	0	M. Agric.	Alf.	.069	2.349	167.3	5702.9	.1400	.1374	1.096
3639B1	2.61	25.2	25.2	47.5	2.1	0	0	Mixed	Alf.	.050	1.554	110.6	3418.3	.1017	.0998	1.100
3639C1	2.36	23.8	6.5	69.7	0	0	0	M. Agric.	Alf.	.043	1.827	96.2	4114.3	.1492	.1464	1.103
3639D2	0.30	6.7	3.3	43.3	46.7	0	0	Urban	Alf.	.078	1.588	169.9	3458.4	.0926	.0909	1.106
3639F1	2.94	15.4	9.5	71.4	0.3	3.4	0	M. Agric.	Alf.	.09a	2.448	197.5	4944.5	.1528	.1499	1.109
3639H1	6.90	39.6	10.4	48.4	1.1	0.4	0.1	Mixed	Alf.	.022	1.153	114.4	2940.1	.1036	.1016	1.114
Lower St. Regis																
3640A1	0.66	92.7	0	0	1.8	5.5	0	Forest	Spod.	.013	0.798	42.6	2613.1	0	0	1.663

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STATE / WATERSHED / Sub Stores #	Area (mi^2)	Land Use Percentages: For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l): Tot P	Tot N	Export ($lbs/mi^2/yr$): Tot P	Tot N	Animal Density (an. units/acre): Tot P	Tot N	Flow (CFSM)**
MICHIGAN																
CharTevoix																
2617B1	11.23	52.9	6.0	40.7	0	0.4	0	M. For.	Spod.	.009	1.947	29.1	6461.7	.1062	.1054	1.600
2617D1	17.33	40.6	3.2	54.3	0.6	0.6	0.7	M. Agric.	Spod.	.012	1.436	25.9	3039.5	.1330	.1325	1.068
2617E1	78.05	73.4	7.1	18.6	0.2	0.5	0.2	M. For.	Spod.	.014	1.199	75.7	5717.6	.0324	.0320	2.404
Thornapple																
2683B1	55.92	19.2	1.0	77.2	0.3	1.6	0.7	Agric.	Alf.	.077	1.863	113.9	2749.9	.1735	.1691	0.762
Crystal																
2694B1	2.89	26.4	14.1	58.5	1.0	0	0	M. Agric.	Spod.	.038	1.621	75.2	3188.9	.0801	.0796	0.756
WISCONSIN																
Butternut																
5509A1	21.81	45.2	8.0	9.9	1.0	35.3	0.6	Mixed	Spod.	.033	0.918	73.5	2065.2	.0274	.0273	1.042
5509A3	22.29	46.7	7.4	8.0	0	37.2	0.7	Mixed	Spod.	.033	1.037	64.8	2035.1	.0222	.0221	1.017
5509B1	7.93	35.3	10.2	22.7	0	31.8	0	Mixed	Spod.	.041	1.282	98.9	3097.8	.0629	.0627	1.083
Delevan																
5513B1	16.80	1.3	7.8	84.6	6.1	0	0.2	Agric.	Alf.	.095	1.602	87.5	1460.1	.2855	.2513	0.506
Eau Claire																
5515B1	39.19	40.7	5.7	48.3	0.7	4.5	0.1	Mixed	Ent.	.108	1.825	146.2	1905.6	.1777	.1773	0.671
5515B2	14.02	7.6	7.7	81.0	1.7	2.0	0	Agric.	Ent.	.184	2.082	243.7	2751.1	.3051	.3040	0.671
5515C1	29.39	59.1	6.5	32.1	0	2.3	0	M. For.	Ent.	.068	1.450	95.2	2306.4	.1107	.1107	0.703
Kegonsa																
5520B1	25.56	5.3	7.4	84.5	1.3	1.0	0.5	Agric.	Alf.	.134	6.424	97.9	4851.7	.3481	.3397	0.353
5520C1	5.81	6.3	7.2	80.3	0	6.0	0.2	Agric.	Alf.	.235	3.704	163.2	2577.6	.3368	.3228	0.354
5520D1	2.53	8.5	2.3	88.7	0	0	0.5	Agric.	Alf.	.184	3.371	128.0	2346.0	.3654	.3566	0.354
Shawano																
5539C1	15.00	9.4	0.8	72.5	0.2	14.0	3.1	M. Agric.	Spod.	.050	1.426	74.8	2133.6	.2842	.2835	0.655
Tainter																
5546B1	17.73	36.3	2.8	49.5	0	10.9	0.5	Mixed	Alf.	.128	1.454	104.3	1496.7	.1745	.1731	0.490
Wapogassett																
5550C1	3.44	16.5	6.0	55.0	0	22.5	0	M. Agric.	Alf.	.111	1.783	111.7	1794.3	.2167	.2162	0.511

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Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export ($lbs/mi^2/yr$) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
WISCONSIN																
Wausau																
5551C1	40.32	17.5	3.3	77.7	1.0	0.4	0.1	Agric.	Alf.	.114	2.110	169.5	3131.5	.3163	.3153	0.754
5551C3	13.20	20.5	4.6	72.4	2.1	0	0.4	M. Agric.	Alf.	.089	1.949	132.1	2892.5	.2947	.2938	0.754
Winnebago																
5554B1	17.12	7.5	2.6	83.7	5.0	1.2	0	Agric.	Alf.	.195	3.641	142.5	2662.5	.2955	.2904	0.358
5554C1	19.70	5.4	3.4	82.9	6.1	1.1	1.1	Agric.	Alf.	.179	3.150	139.2	2443.6	.2926	.2877	0.356
5554E1	6.81	4.9	0	94.2	0.9	0	0	Agric.	Alf.	.233	2.523	168.0	1818.7	.3329	.3272	0.366
Wisconsin																
5555D1	45.38	16.0	2.9	78.9	1.0	1.1	0.1	Agric.	Ent.	.088	2.069	120.4	2833.6	.3077	.2919	0.696
5555D2	9 93	9.7	0.9	88.4	1.0	0	0	Agric.	Ent.	.059	2.414	80.8	3305.7	.3448	.3271	0.696
5555E1	42.52	14.5	1.4	79.1	2.0	3.0	0	Agric.	Alf.	.078	2.511	103.7	3701.9	.3206	.3104	0.696
5555E2	33.71	15.0	1.4	78.4	1.7	3.5	0	Agric.	Alf.	.131	2.569	179.4	3517.9	.3178	.3076	0.696
Wissota																
5556D1	55.29	37.7	4.5	56.1	0	1.7	0	M. Agric.	Ent.	.085	1.872	107.1	2356.9	.2113	.2105	0.639
Tichigan																
5559A4	126.39	6.1	7.6	60.9	16.3	4.9	4.2	M. Agric.	Alf.	.158	2.133	157.3	2253.5	.1815	.1803	0.508
Big Eau Pleine																
5565B1	32.08	31.8	4.4	63.0	0.6	0	0.2	M. Agric.	Alf.	.102	1.866	155.1	2832.7	.2564	.2557	0.668
5565C1	22.91	34.7	4.7	58.2	0	0	2.4	M. Agric.	Alf.	.066	2.453	66.7	3677.8	.2369	.2362	0.658
Grand																
5570B1	16.55	10.9	8.1	79.4	1.6	0	0	Agric.	Alf.	.259	4.335	165.8	3476.8	.3017	.2930	0.360
Beaverdam																
5577C1	33.57	9.8	7.0	73.6	1.1	8.5	0	M. Agric.	Alf.	.208	3.040	245.5	3828.2	.2885	.2804	0.586
5577C2	23.54	10.0	6.1	71.7	0	12.2	0	M. Agric.	Alf.	.224	2.722	258.3	3139.0	.2782	.2696	0.586
5577E2	1.66	0	0	99.1	0.9	0	0	Agric.	Alf.	.136	7.472	168.7	9267.0	.4033	.3964	0.630

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WATERSHED Sub Storet #	Area (mi^2)	Land Use Percentages For.	Cl.*	Ag.	Urb.	Wet.	Other	Overall Land Use Category	Soil Order**	Mean Conc. (mg/l) Tot P	Tot N	Export ($lbs/mi^2/yr$) Tot P	Tot N	Animal Density (an. units/acre) Tot P	Tot N	Flow (CFSM)***
MINNESOTA																
Big Stone																
2709D1	13.52	2.6	2.3	95.0	0	0	0.1	Agric.	Moll.	.089	0.881	22.2	219.4	.1123	.1093	0.104
2709E1	5.82	3.9	1.6	94.5	0	0	0	Agric.	Moll.	.052	3.103	20.9	1249.0	.1117	.1087	0.107
2709F1	24.01	1.8	2.0	96.2	0	0	0	Agric.	Moll.	.053	1.431	12.3	330.9	.1137	.1106	0.106
Buffalo																
2713C1	2.39	9.4	0	74.1	15.2	1.3	0	M. Agric.	Moll.	.186	2.119	251.4	2854.6	.2364	.2327	0.577
Cokato																
2719B2	20.04	4.8	0.1	75.0	2.3	15.2	2.6	Agric.	Alf.	.326	3.942	209.4	2160.1	.2363	.2325	0.373
2719C1	3.79	5.1	0	89.8	0	5.1	0	Agric.	Alf.	.202	4.626	154.3	3533.1	.2865	.2820	0.388
Heron																
2739H1	2.41	1.0	1.1	97.8	0	0	0.1	Agric.	Moll.	.099	4.676	54.7	2591.5	.2172	.2057	0.179
Mashkenode																
2756B1	6.67	41.4	14.7	1.2	27.8	1.1	13.8	Mixed	Alf.	.036	1.313	36.6	1335.7	.0023	.0022	0.517
Sakatah																
2777B1	34.11	6.2	1.1	79.9	0.7	11.5	0.6	Agric.	Alf.	.233	5.320	175.5	4006.8	.1774	.1771	0.427
Pepin																
27A4H1	68.26	19.1	1.2	79.6	0	0.1	0	Agric.	Alf.	.231	2.586	194.4	2176.3	.2382	.2338	0.422
27A4J1	24.86	26.8	4.5	68.7	0	0	0	M. Agric.	Alf.	.224	2.057	202.3	1861.6	.2531	.2479	0.455
27A4K1	17.34	19.9	4.2	73.8	2.0	0	0.1	M. Agric.	Alf.	.161	2.390	137.5	2042.3	.2983	.2919	0.423
Zumbro																
27A5F1	0.19	0	0	76.2	23.8	0	0	Agric.	Moll.	.121	2.216	88.4	1624.4	.2631	.2563	0.371
27A5G1	30.23	7.7	0	92.3	0	0	0	Agric.	Moll.	.081	3.634	50.0	2249.5	.3000	.2935	0.326
St. Croix																
27A7C1	5.82	13.4	4.8	81.5	0	0	0.3	Agric.	Moll.	.053	1.951	70.4	2599.9	.2252	.2225	0.678

*Cl. . . . . .Cleared - unproductive

**Soils:
Alf . . . . . .Alfisols
Incp . . . . . Inceptisols
Moll . . . . . Mollisols
Spod . . . . . Spodosols
Ent . . . . . .Entisols

***CFSM . . . . . Cubic feet/second/square mile

A. Overall Land Use vs. Nutrient Runoff

Individual drainage areas are assigned overall land use categories according to the following criteria:

1. Forest; other types negligible

   a. >75% forest (including forested wetland).
   b. <7% Agriculture
   c. <2% urban

2. Mostly forest; other types present

   a. >50% forest
   b. ≠ forest category

3. Mostly agriculture; other types present

   a. >50% agriculture
   b. ≠ agriculture category

4. Agriculture; other types negligible

   a. >75% agriculture
   b. <7% urban

5. Urban

   >39% urban

6. Mixed

   ≠ any of categories 1 - 5

The relationships between these overall land use categories and nutrient runoff are graphically illustrated in Figures 2 through 5. It should be emphasized that these graphs contain mean annual nutrient stream values from the entire nine-state area and do not reflect regional relationships. For example, one should not conclude from Figure 2 that total phosphorus concentrations in streams draining "mostly agricultural" areas in Vermont and New York will average about 0.076. From analysis of other values in the same geographical region, an average regional value would probably be somewhat smaller. Obviously, other interrelated factors such as slope, soils, climate, etc., come into play.

However, Figures 2 through 5 illustrate some significant overall relationships. Nutrient concentrations are significantly lower in streams draining forested areas than in streams draining areas that are used primarily for agricultural purposes. This is true for both nutrients but to a greater degree for total phosphorus than total nitrogen. Earlier preliminary work indicated even greater differences in orthophosphorus concentrations as compared to those for total phosphorus. Similarly, greater differences were noticed in inorganic nitrogen concentrations as compared to those for total nitrogen. Analysis of these other forms haven't been included in this report but will be included in subsequent reporting on all study areas east of the Mississippi.

Figure 2. MEAN TOTAL PHOSPHORUS CONCENTRATIONS VS LAND USE

DATA ON 143 SUBDRAINAGE AREAS IN NORTHCENTRAL AND NORTHEASTERN UNITED STATES.

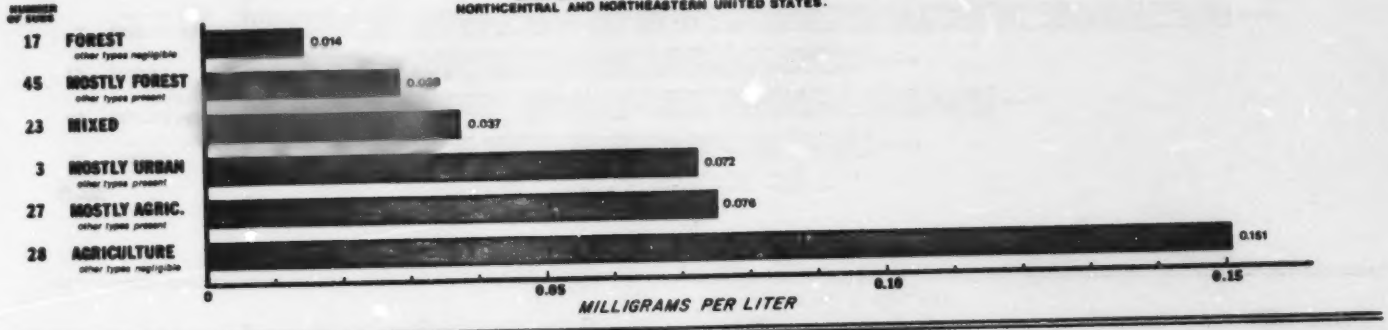


Figure 3. MEAN TOTAL NITROGEN CONCENTRATIONS VS LAND USE

DATA ON 143 SUBDRAINAGE AREAS IN NORTHCENTRAL AND NORTHEASTERN UNITED STATES.

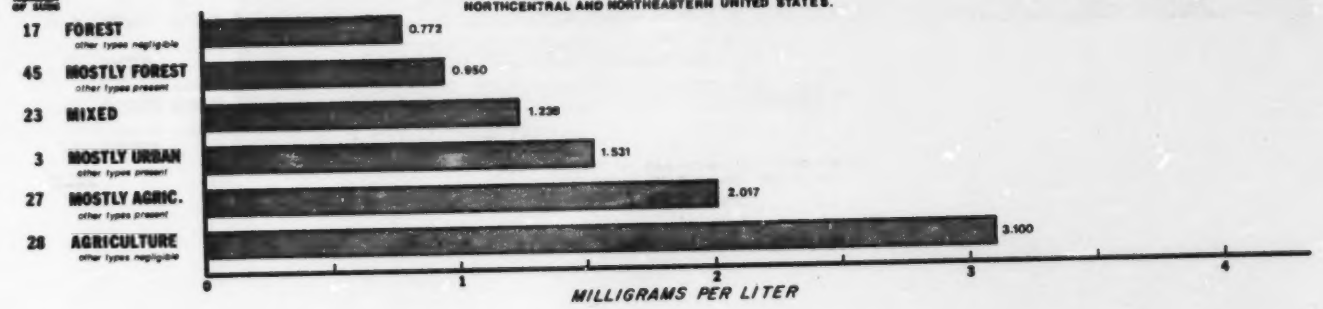


Figure 4. **TOTAL PHOSPHORUS EXPORT VS LAND USE**

DATA ON 143 SUBDRAINAGE AREAS IN NORTHCENTRAL AND NORTHEASTERN UNITED STATES.

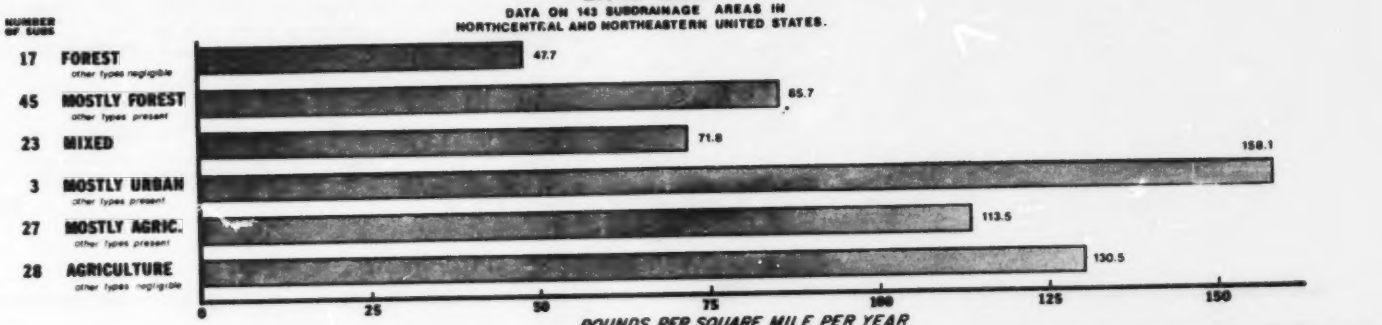
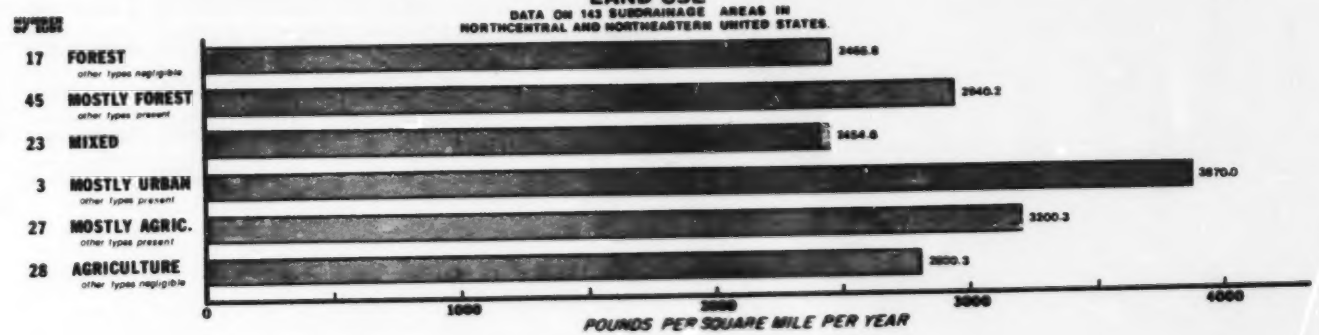


Figure 5. **TOTAL NITROGEN EXPORT VS LAND USE**

DATA ON 143 SUBDRAINAGE AREAS IN NORTHCENTRAL AND NORTHEASTERN UNITED STATES.



It is interesting to note that the relationships between nutrient export and land use are not nearly as dramatic as those between concentrations and land use. As a matter of fact, when considering total N export vs. overall land use, there appears to be very little relationship. The mean concentrations in streams draining homogeneous agricultural areas were almost 11 times greater in total phosphorus and over four times greater in total nitrogen, than in streams draining purely forested land. However, when dealing with export values from the same data points, the mean total P export value for agricultural areas is only about 2.7 times greater than that for forested watersheds; the difference in total N export is only about 14%. Partial explanation of the difference between concentrations vs. land use and export vs. land use lies in the strong correlation ($r = .8$) between runoff (in cubic feet/sec./mi^2) and the percent of the subdrainage area in forest. This in turn is probably due in large part to greater average slopes in the forested drainage areas than in the agricultural watersheds. Moreover, the presence of urban land usage seems to have a pronounced effect on the amount of export. Here again, the cause is probably due to increased flow rates, but in this case mainly because of greater areas of impervious surfaces.

For additional help in understanding the difference between concentrations vs. land use and export vs. land use, it is important to recognize that the drainage areas included in this study are not control plots,

rather they are natural drainage areas and by in large represent typical land use- and geographical-related characteristics in their respective areas. If one were studying control plots where slope, soil type, and climate conditions were similar from one plot to another, one would expect a significantly higher nutrient export rate (as well as a higher nutrient concentration) from plots in agricultural land use than from forested plots. Runoff as well would probably be somewhat greater from agricultural plots than from forested plots. Natural drainage areas, on the other hand, possess different topographic, soils, and climatic characteristics. These characteristics are in turn important in determining land usage in the first place. In general, flat to rolling terrain and rich soils, such as are found in southern Minnesota, lend themselves to agricultural land use. Conversely, where the terrain is too mountainous or dissected or the soil too poor for agriculture to be economically feasible, such as in much of New England, forests are allowed to predominate.

The fact that subdrainage areas categorized as forest are on the average considerably smaller than subdrainage areas categorized as agriculture suggests a possible relationship between nutrient concentration and subdrainage area size. To investigate this possibility, scattergrams were constructed for nutrient concentrations vs. drainage area sizes for both agriculture and forest land use categories, but they revealed no significant relationships.

B. Nutrient Concentration vs. Percent Forest

1. Phosphorus concentrations vs. percent forest

Figure 6 shows the relationship between total phosphorus concentations in streams (PCONC) and the percent of the subdrainage areas in forest land (FOR). Although the slopes of separate logarithmic regressions for the two geographic regions (northcentral and northeast) are not significantly different, the ratio of average concentrations in the two geographic regions is substantially larger than would be predicted by the slope of the regression line. Thus, two parallel regression lines have been fit.

It appears likely that the difference in concentrations between the two regions is due more to such factors as topography (particularly slope) and soil type than to land use patterns. On the other hand, these factors are closely interrelated; slope and soils play an important role in shaping land use. In a future report on the approximately 380 areas in the '73 study area, to be added to the '72 areas, data on slope and soils will be included in the analysis. The three northern Michigan areas, having soils similar to those in the northeast region, fit the northeast regression line much better than the northcentral one. They

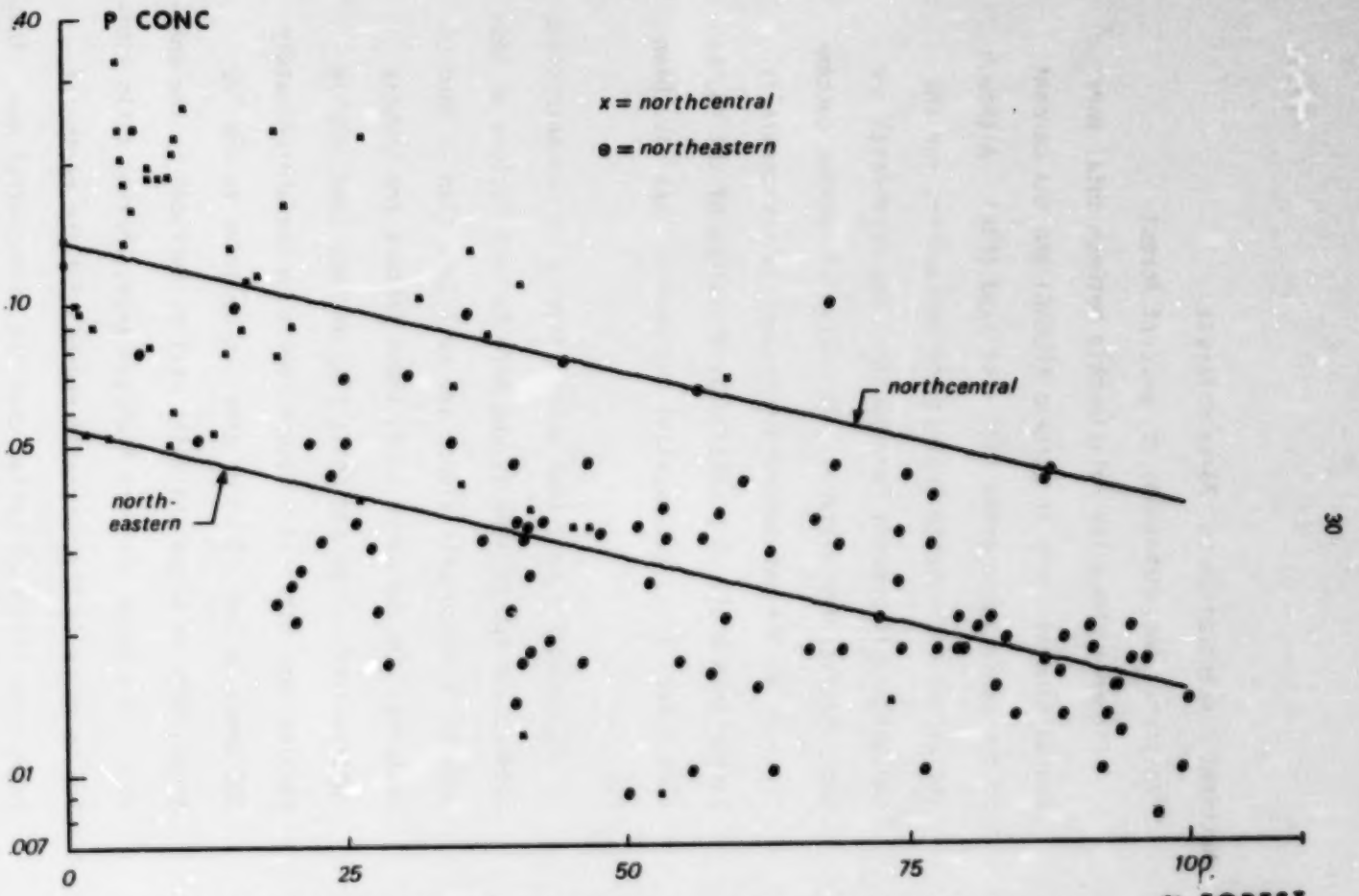


Figure 6. Mean Total Phosphorus Concentrations (in milligrams per liter) vs. Percent of Drainage Area in Forest

have been deleted for purposes of regression fitting, but show on Figure 6 as the three lowest PCONC values.

The equations of the regression lines shown in Figure 6 are:

$$\text{Log}_{10}\ (\text{PCONC}) = -.870 - .0057\ (\%\text{FOR})$$

for the northcentral areas and

$$\text{Log}_{10}\ (\text{PCONC}) = -1.263 - .0057\ (\%\ \text{FOR})$$

for the northeastern areas.

In addition to a negative correlation between phosphorus concentrations in streams and percent of land in forest, these data indicate that one would expect phosphorus concentrations in streams draining forested areas to be about 2.5 times higher in the northcentral region than in the northeastern region. Although the overall correlation between phosphorus concentrations in streams and percent of drainage areas in forest was significant ($r = -.75$), and although the fitting of separate means to the two regions gave an apparently larger proportion of "predictability" than did the phosphorus concentration-percent forest relationship, because of the low correlations <u>within regions</u> ($r = -.48$ for the northcentral region and $r = -.53$ for the northeastern region) the above equations do not allow phosphorus concentration predictions to be made with a great degree of certainty.

2. Nitrogen Concentrations vs. percent forest

Figure 7 shows the relationship between total nitrogen concentrations in streams (NCONC) and the percent of the subdrainage areas in forest land (FOR). Again, as with phosphorus concentrations vs. percent forest, the northcentral region has higher nitrogen concentrations in streams than would follow from just the relation to percent forest, but the difference is only about one-half of that for phosphorus. The equations of the regresssion lines in Figure 7 are:

$$\text{Log}_{10}\ (\text{NCONC}) = .464 - .0058\ (\%\ \text{FOR})$$

for the northcentral areas and

$$\text{Log}_{10}\ (\text{NCONC}) = .344 - .0058\ (\%\ \text{FOR})$$

for the northeastern area.

Comparison of the two equations indicate that one would expect nitrogen concentrations in streams draining forested areas to be 1.32 times higher in the northcentral region than in the northeastern region. For nitrogen as opposed to phosphorus, a larger proportion of the "predictability" is due to the forest relationship rather than the geographic region. The average "within regions" correlation coefficient for nutrient concentrations in streams-percent forest relationships is about -.64 for nitrogen as compared with -.51 for phosphorus. This together with a more linear overall distribution of data points in Figure 7 as compared with Figure 6

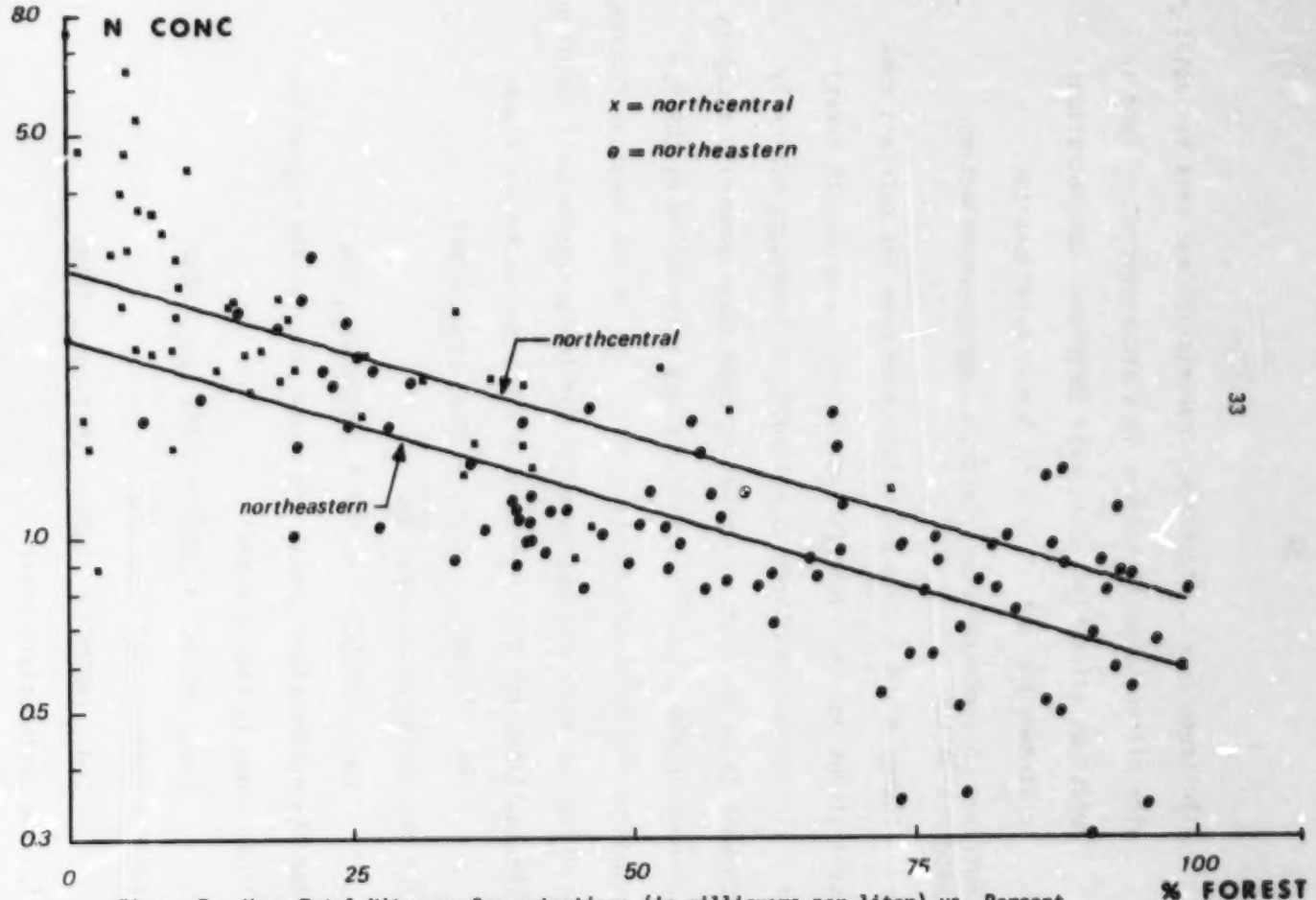


Figure 7. Mean Total Nitrogen Concentrations (in milligrams per liter) vs. Percent of Drainage Area in Forest

illustrate a more significant correlation and less variability with nitrogen concentrations in streams-percent of land in forest relationships, than with phosphorus concentrations in streams-percent of land in forest relationships.

C. Nutrient Concentrations vs. Contributing/non-contributing Land Use Ratios

Figures 8 and 9 show the relation between the nutrient concentrations and the ratio (% agriculture + % urban)/(% forest + % cleared-unproductive + % wetland), or land uses generally thought to be nutrient contributing over those generally accepted as non-contributing. This variable was referred to as CNR for contributing to noncontributing ratio. As in the previous figures, a different intercept has been fit for the two geographic locations. The equations for the regression lines shown in Figure 8 are:

$$\text{Log}_{10}\,(\text{PCONC}) = -1.086 + .2153\ \text{Log}_{10}\,(\text{CNR})$$

for the northcentral areas and

$$\text{Log}_{10}\,(\text{PCONC}) = -1.482 + .2153\ \text{Log}_{10}\,(\text{CNR})$$

for the northeastern areas. The equations for the regression lines shown in Figure 9 are:

$$\text{Log}_{10}\,(\text{NCONC}) = .2607 + .1853\ \text{Log}_{10}\,(\text{CNR})$$

for the northcentral areas and

$$\text{Log}_{10}\,(\text{NCONC}) = .1025 + .1853\ \text{Log}_{10}\,(\text{CNR})$$

for the northeastern areas.

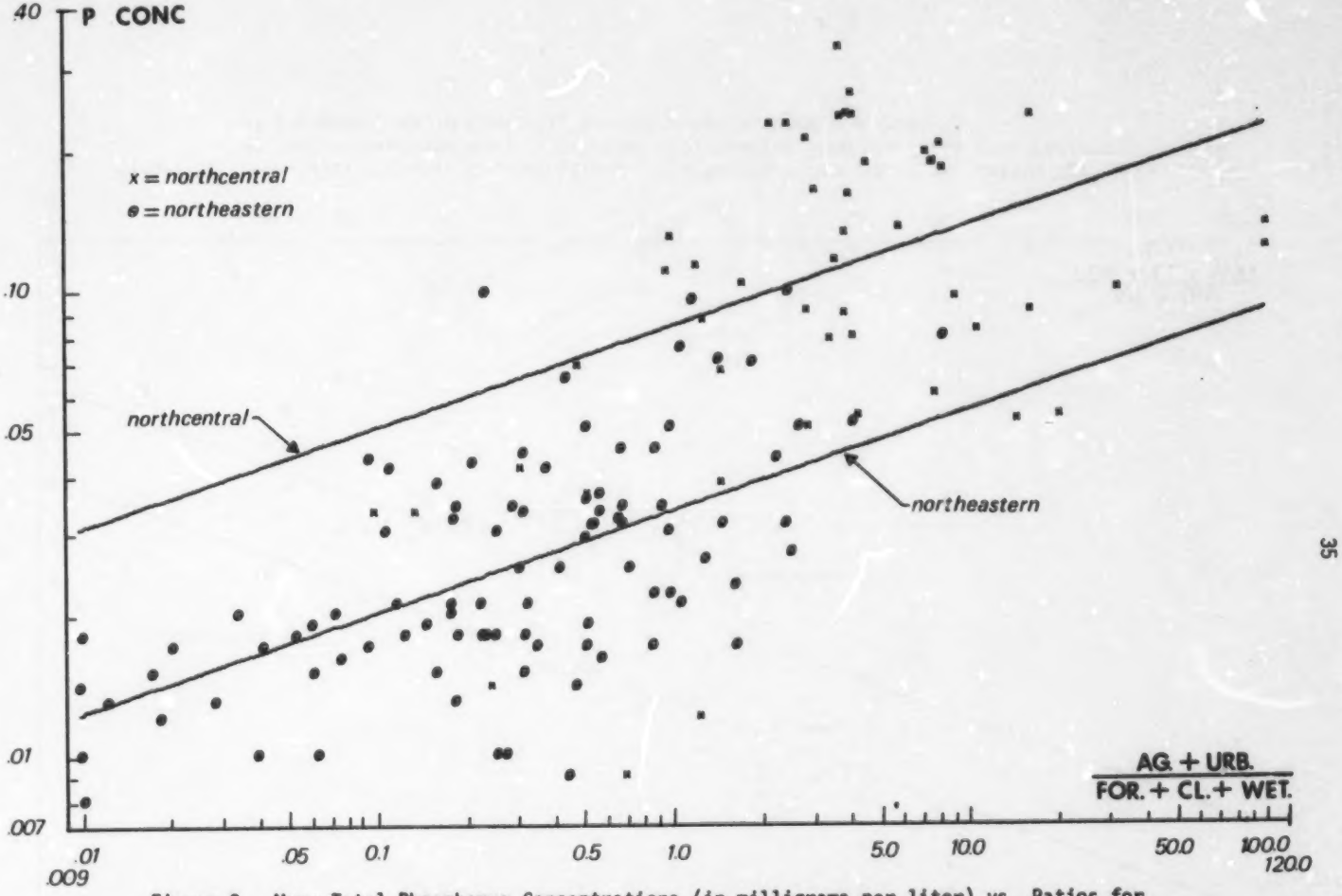


Figure 8. Mean Total Phosphorus Concentrations (in milligrams per liter) vs. Ratios for Percent of Drainage Area in Nutrient Contributing Land Use Types over Percent of Drainage Area in Generally Non-contributing Land Use Types

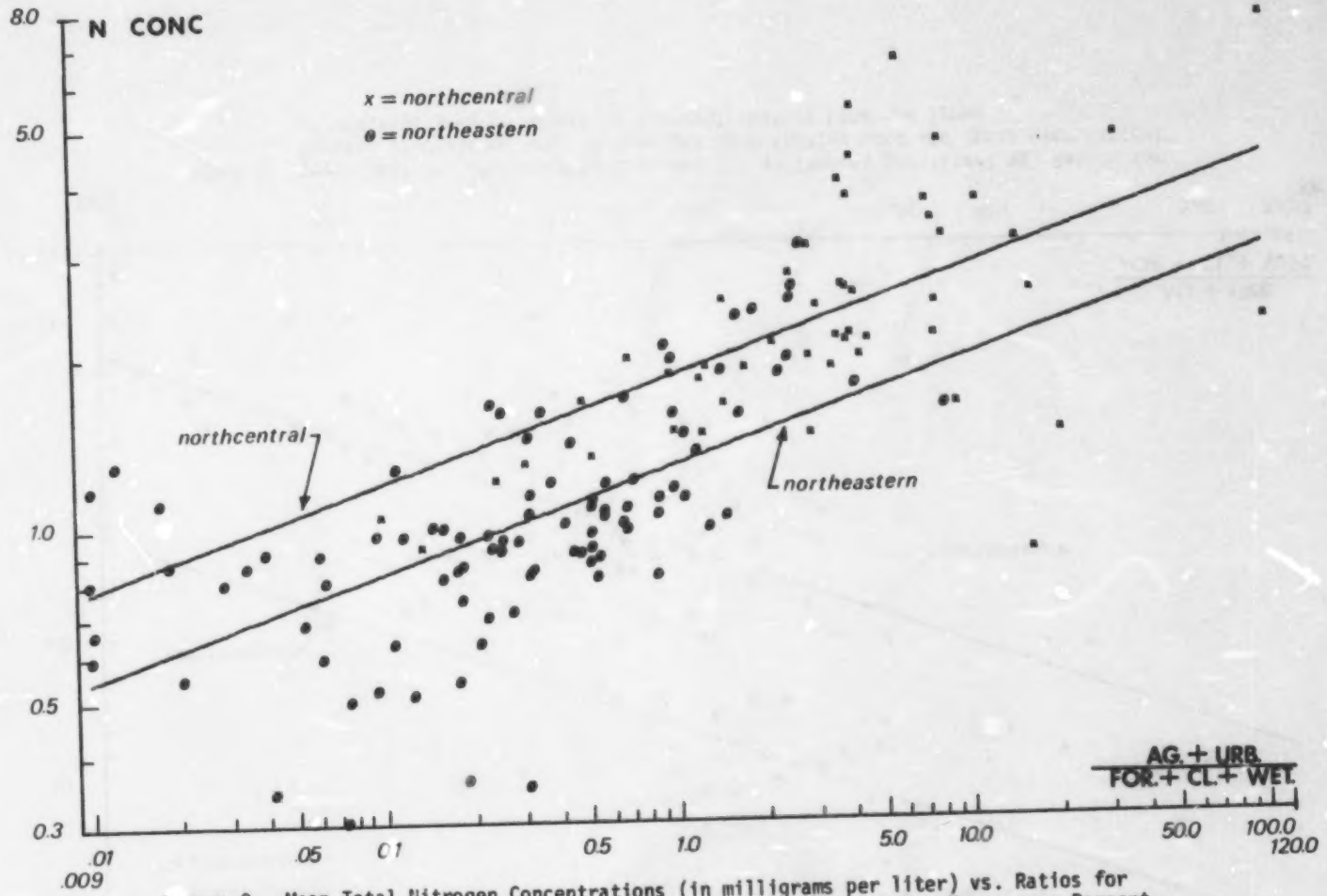


Figure 9. Mean Total Nitrogen Concentrations (in milligrams per liter) vs. Ratios for Percent of Drainage Area in Nutrient Contributing Land Use Types over Percent of Drainage Area in Generally Non-contributing Land Use Types

These figures illustrated regional differences similar to those shown in Figures 6 and 7. The correlations (r = .74 for PCONC vs. CNR, and .76 for NCONC vs. CNR) appear to be nearly as significant as those exhibited by the nutrient concentrations vs. percent forest relationships.

D. Nutrient Export vs. Percent Forest

Figures 10 and 11 illustrate very little relationship between the export of either nutrient and the percent of the subdrainage area in forest land. The probable reasons for this were briefly discussed in an earlier section on overall land use vs. nutrient runoff. As it was pointed out, a strong correlation was found between flow and percent of the subdrainage area in forest, which in turn was due to some extent to the greater average slope in forested drainage areas as opposed to agricultural watersheds. Differences in soil porosity from one region to another are likely to have a bearing on these relationships also. It should be noted that while average annual precipitation in the '72 study area in general only varied from about 24" to about 48", normalized annual surface runoff varied from 0.1 to over 2.0, or a variance 10 times greater than that for precipitation. Moreover, cursory examination of USGS surface water records revealed little correlation between drainage area size and flow per unit area within drainage basins. The net effect of the positive correlation between flow and % forest

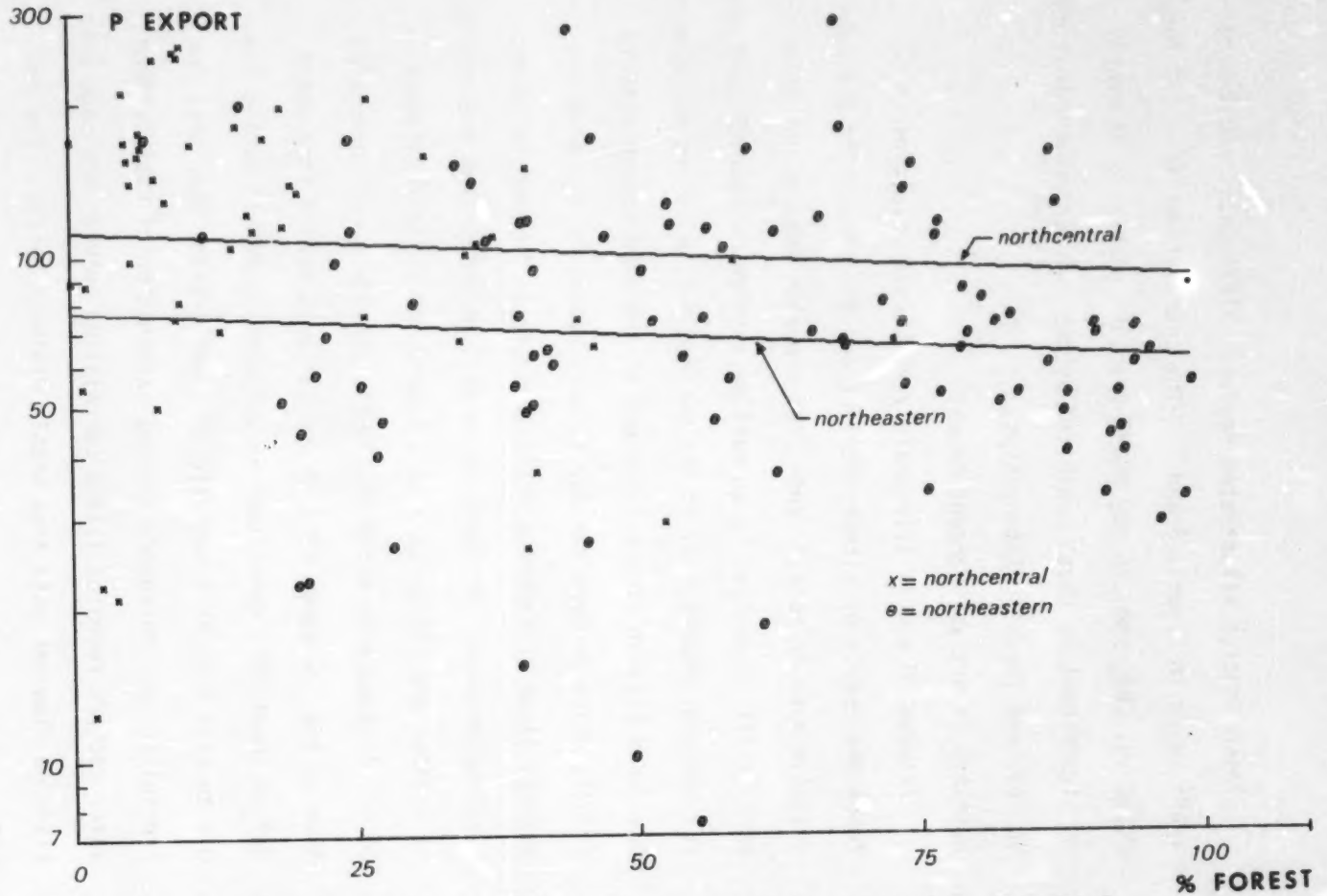


Figure 10. Total Phosphorus Export (in pounds per square mile per year) vs. Percent of Drainage Area in Forest

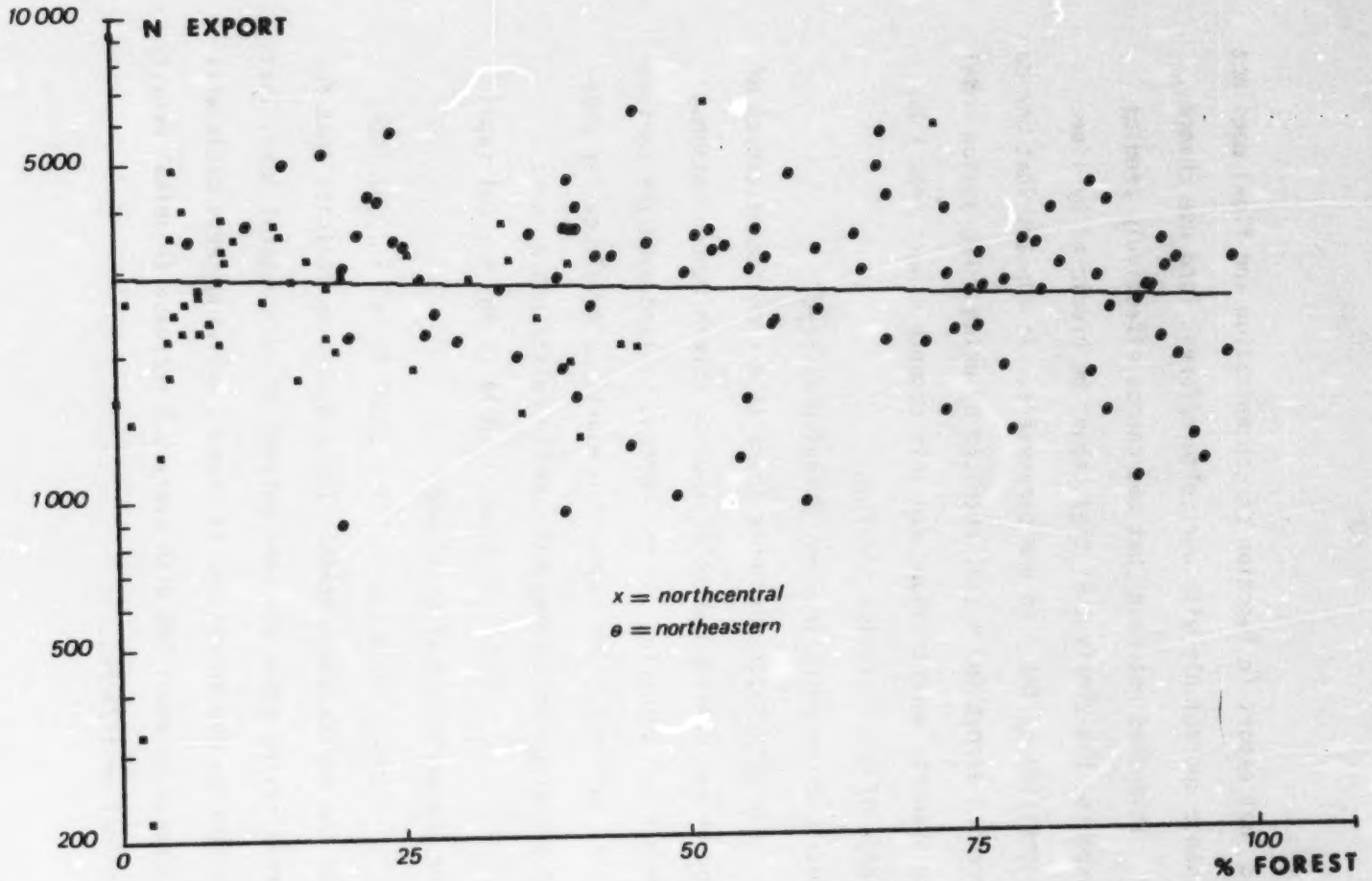


Figure 11. Total Nitrogen Export (in pounds per square mile per year) vs. Percent of Drainage Area in Forest

is that export (a function of concentration and flow) does not change appreciably with agriculture/forest land use changes.

This does not mean that one cannot effectively predict exports, but simply that they cannot be predicted by linear regression on the land use parameters. It appears that one can predict export for either nutrient by using a regression model to predict concentration, and then compute export from knowledge of concentration and flow.

E. Nutrient Concentrations vs. Animal Densities

For both major nutrients there is a significant effect of the animal density parameter (AD) on stream concentrations, even after adjusting for the percent of land used for agricultural purposes. The regression equations developed for phosphorus concentration-animal density relationships are:

$$\text{Log}_{10}\ (\text{PCONC}) = -1.387 + .0024\ (\%\ \text{Ag}) + 1.081\ (\text{ADP})$$

for the northcentral areas and

$$\text{Log}_{10}\ (\text{PCONC}) = -1.733 + .0024\ (\%\ \text{Ag}) + 1.081\ (\text{ADP})$$

for the northeastern areas. These equations indicate that for areas having about the same percent of agricultural land, that phosphorus concentrations in streams draining these areas will increase by about 28% with every 0.1 increase in animal density (animal units/acre).

The regression equations developed for nitrogen concentrations-animal density relationships are:

$$\text{Log}_{10}\ (\text{NCONC}) = -.045 + .0043\ (\%\ \text{Ag}) + .490\ (\text{ADN})$$

for the northcentral areas and

$$\text{Log}_{10}\ (\text{NCONC}) = -.139 + .0043\ (\%\ \text{Ag}) + .490\ (\text{ADN})$$

for the northeastern areas. These equations suggest that for areas having about the same percent agricutural land, that nitrogen concentrations in streams draining these areas will increase by about 12% with an 0.1 increase in animal density.

F. Prediction of Concentrations

There are many ways that the land use parameters might be used in regression type models to predict nutrient concentrations. As further data and additional parameters are analyzed, it may be found that the following models are not of the best form. They do indicate, however, roughly what can be done. The use of pH values, soil types, and topographic parameters will likely allow somewhat better predictions. More important, the addition of soil characteristics and/or types, and topographic parameters may enable a means of predicting changes in nutrient concentrations and loadings in streams associated with land use changes in watersheds.

A possible prediction model for phosphorus concentrations in streams is:

Log_{10} (PCONC) = constant - .00126 (% FOR) + .00185 (% AG) + .0114 (% URB) + 1.180 (ADP)

where the constant is -1.382 for the northcentral region and -1.690 for the northeastern region.

The difference of .308 in the constant for the two regions means that, all other variables being taken at equal values, phosphorus concentrations are about two times higher in the north-central region than in the northeastern region.

A possible model for nitrogen concentrations in streams is:

Log_{10} (NCONC) = constant - .00346 (% FOR) + .00110 (% AG) + .00169 (% URB) + .6366 (ADN)

where the constant is .2013 for the northcentral region and .1306 for the northeastern region.

The difference of .0707 in the constant for the two regions can be interpreted to mean that, all other variables taken as equal, phosphorus concentrations are only about 18% higher in the northcentral region than in the northeast.

Although these models point out a significant increase in the predictability of nutrient concentrations in streams through the use of land use parameters, over simply using mean values of all the data points regardless of land use parameters, the models

only indicate the correlations that are found to exist between land use patterns and nutrient concentrations in streams. It does not follow that the models can be used to predict changes in concentrations with associated changes in land use. It is speculated that the introduction of additional parameters to account for soil, topographic, and climatic characteristics, that played an important role in determining existing land use, may make these types of predictions possible.

G. Nutrient Runoff—Soils Relationships

In general, the analysis of land use vs. nutrient runoff data from the '72 study area has been confined to general land use categories, and the effects of animal densities. The addition of more data points in future reporting will allow more detailed study of spatial interrelationships with other factors; and, hence, the probable introduction of one or more of these factors to prediction models.

However, even when considering the few drainage areas included in the '72 study area, the effects of soils on nutrient concentrations in streams seemed apparent. Comparisons of general soils maps with the NES drainage areas, stream nutrient concentrations, and land use ratios maps mentioned earlier, indicated some strong correlations. For the most part, streams draining areas with soil orders characteristically high in bases, have high nutrient concentrations, whereas streams draining areas with mostly acid-type soils are low in nutrient concentrations. Data on nutrient concentrations by soils order, for the '72 study area watersheds, are presented in Table 6. The soils are listed in order of their overall pH characteristics, from acidic to basic.

TABLE 6

Mean Nutrient Concentrations by Drainage Area Soil Orders

Soil Order	Number of Drainage Areas	Conc. (mg/l) Total P	Total N
Spodosols	47	0.025	0.93
Inceptisols	27	0.032	1.05
Alfisols	55	0.094	2.30
Mollisols	8	0.137	2.40

Obviously, a great number of the drainage areas with spodosols are mostly forested, and most of the drainage areas with soils characteristicly high in pH are agricultural. In an attempt to understand whether the soils-nutrient concentration relationship has any meaning, and possibly helps explain the "regionality" of nutrient concentrations vs. land use, the data in Table 6 were subdivided by land usage, and are presented in Table 7. Because

TABLE 7

Mean Nutrient Concentrations by Drainage Area Soil Order, and Subdivided by General Land Use

Total Phosphorus Concentrations

Soil Order	Mostly Agric. (mg/l)	Number of Drainage areas	Mostly Forest (mg/l)	Number of Drainage areas
Spodosols	0.032	4	0.020	37
Inceptisols	0.039	3	0.026	17
Alfisols	0.125	36	0.027	7
Mollisols	0.137	8	--	0

Total Nitrogen Concentrations

Soil Order	Mostly Agric. (mg/l)	Number of Drainage Areas	Mostly Forest (mg/l)	Number of Drainage Areas
Spodosols	1.378	4	0.855	37
Inceptisols	1.215	3	0.933	17
Alfisols	2.900	36	0.958	7
Mollisols	2.405	8	--	0

of the limited number of data points in individual land use categories, homogenous "agriculture" categories and less homogenous "mostly agriculture" categories were combined and referred to as mostly agriculture; "forest" and mostly forest" categories were handled similarly. Although data interpretation must be somewhat qualified because of the small number of drainage areas in some categories, the differences in mean concentrations between soil orders are believed to be significant, particularly for total phosphorus in agricultural drainage areas.

IV. CONCLUSIONS

Based on analysis of land use and stream nutrient runoff data compiled for 143 stream drainage areas sampled during the first year of the National Eutrophication Survey, the following statements can be made:

1. Mean annual nutrient concentrations were found to be significantly higher in streams draining agricultural lands than in streams draining primarily forested watersheds. These differences were considerably greater for total phosphorus (0.151 to 0.014 mg/l) than for total nitrogen (3.100 to 0.772 mg/l).

2. Less variablility was noted in total nitrogen stream concentrations and loadings than for total phosphorus.

3. Little to no correlation was found between nutrient export and overall land use. However, a positive correlation between flow and percent forest ($r = .8$) indicated the probable "dilution" of a nutrient export-land use correlation, if existent. Cursory analysis of soils, topography, and climate suggest this compensating effect and indicate the need to consider these aspects in the development of possible export prediction models, to be accomplished in the next phase of this study.

4. Separate regression analyses of total phosphorus and total nitrogen concentrations against percent of drainage areas in forest illustrated a significant relationship but not enough to provide much predictive ability. By identifying the data points by geographic region (northcentral and northeastern) and computing separate logarithmic regressions for each of the regions, a better "predictability" was attained. The scatter diagrams and separate regression lines indicated that for nitrogen, as opposed to phosphorus, a larger proportion of this predictability was due to the forest relationship, rather than the geographic region.

5. For both nitrogen and phosphorus concentrations in streams, the animal density parameter was shown to be of significant effect, even after adjusting for percent of drainage area in agricultural land.

6. Preliminary nutrient concentration prediction models were constructed for both phosphorus and nitrogen, but their use is somewhat qualified. It appears that the addition of other parameters to the model (slope, soils, climate, etc.) should increase their utility.

7. Preliminary analysis of relationships between soils and nutrient concentrations in streams have indicated significant correlations between pH characteristics in soils and nutrient concentrations, even within drainage areas having similar land use types. Generally, concentrations were found to be considerably higher in streams draining areas with soil orders characteristically high in bases, than in streams draining areas with mostly acid-type soils.

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